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THE WIND TUNNEL OF THE SHIPBUILDING INSTITUTE OF HAMBURG UNIVERSITY

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(From German)

In the Shipbuilding Institute of Hamburg University a wind tunnel, built with the help of funds from the German Research Association, Hamburg University and the Institute, has recently been put into operation.

It may perhaps seem surprising that here, far from the centres of aeronautical research, an experimental installation has come into being, about which one usually hears in connection with aircraft, rockets, or gas turbines. There are of course aerodynamic problems in shipbuilding, such as the air resistance of superstructures, or the optimum design of funnels for carrying away smoke in different wind directions. This group of problems, however, is only of relatively secondary importance.

There is also a number of more important questions concerning the flow along a ship below the waterline which can also be investigated in a wind tunnel and much more conveniently and cheaply than in a water tunnel or towing tank. Merely by taking into account certain similarity rules, experimental results obtained in the wind tunnel can be applied to water flow. Such problems are, for instance, the pressure distribution and the forces on the underwater ship, even when on a curved course, the properties of various rudders or the forces on the hydrofoils of a hydrofoil boat. These are problems in which the influence of the water surface does not play a decisive part. It is well known, however, that the actual hydrodynamics of the ship is rendered complicated by flow on a free surface, i.e. the water surface. The deformation of this surface, the wave formation, makes it very much more difficult to predict a ship's resistance as compared with the resistance of a body surrounded on all sides by a liquid. It is obviously impossible to imitate such a free surface in the air stream of a wind tunnel. Nevertheless, it was just such a problem which was the chief reason for building the tunnel, namely the separation of frictional and wave resistance by measurements on double models. The resistance of a model of a ship, "reflected" on the waterline, in a wind tunnel corresponds to double the frictional resistance which it experiences when it floats in water. If now the same model is towed in a water tank, we obtain the sum of the frictional resistance and wave resistance. Thus by comparing the coefficients of resistance in the wind tunnel and in the towing test, we can separate the friction and wave components in a fairly direct way, which we know cannot be done by transferring ordinary model measurements to the ship. Of course, instead of this, the double model could be towed submerged or measurements could be made on it submerged in a water tunnel, but this is complicated and costly and has therefore only been done in a few isolated instances.

It is true that such comparison of the resistance in a wind tunnel and in a tank is only rational if the Reynolds numbers are equal. This means that as the kinetic viscosity of air is about thirteen times that of water, for the same model the air velocity must be about thirteen times that of the towing speed in the tank. This condition, however, represents quite manageable velocities for the wind tunnel.

A considerable difficulty with regard to measuring technique arises from the fact that unlike usual aerodynamic test objects, a ship model is very long in the direction of flow compared with its width. We therefore require a wind tunnel with a very long test section in the direction of flow, a condition which up to the present has been possible only in closed tunnels, because in a wind tunnel with open test section, the free jet, in which the measurements are to be made, is rapidly disturbed from the edges

by turbulent mixing with the surrounding quiescent air of the laboratory, so that we get a useful test section of a length of only about $1\frac{1}{2}$ jet diameters. The closed test section has two important disadvantages compared with the open jet. First of all, the tunnel corrections are greater, i.e. the measured velocities, pressures and forces have to be corrected by calculation more considerably than in the case of measurements with the open jet in order to extrapolate the conditions in an air stream which is unconfined in all directions. Secondly, in a closed tunnel, as in a pipe, the static pressure falls off somewhat, even when there is no test object in position. The pressure gradient in the direction of flow, which is influenced of course by the model itself and its wake, is particularly inconvenient, especially in long models.

To avoid these disadvantages of the closed test section without having to investigate such long test bodies in excessively large tunnels of open type, Dr. F. Vandrey and the author a few years ago developed a test section in which over a length of about five diameters, the same flow conditions obtain as in an open jet. This was a cross between an open and closed test section; the construction (see Figure 1) may be regarded as a partly encased free jet or as a closed tunnel which is partly open through longitudinal slots. The air jet is here surrounded by twenty longitudinal strips which cover the peripheral surface of the jet to about 70%. These strips of plexiglass, plastic or the like prevent turbulent mixing of the air in the jet with the quiescent outside air and delay the break-up of the free jet, so that a sufficiently powerful jet core of constant velocity persists, even after a length of some diameters. The slots between the strips furthermore provide a perfectly adequate equalisation of the static pressure in the jet with the outside room, so that it is constant along the entire test section (except for the pressure field of the test body) and is equal to that of the laboratory. Pressure measurements on elongated bodies in a small model of such a "test cage" finally showed that the necessary small tunnel correction corresponded, as expected, to that in a free jet. The correction for long bodies in a free jet was calculated for this purpose by Dr. F. Vandrey in an unpublished report. Thus, in brief, this construction provides an approximation to an ideal free jet (without break-up of the jet). For this reason a test cage of this kind has been provided for the tunnel of the Shipbuilding Institute and is already under construction.

In the first stage of the wind tunnel now completed in the open Göttingen type, a free jet of 1 metre diameter and up to 32 metres per second air velocity is produced. A blower (1.4 metres diameter) with guide blades draws air from the laboratory and forces it through a diffusor into the pressure chamber of 2 metres diameter and through the nozzle with the transverse contraction 4:1. Equalisation of the velocity distribution in the jet is effected by two fine screens, manholes being provided to give access to the tunnel for cleaning these screens. A honeycomb grid of hexagonal brass tubing for straightening the flow is projected but not yet completed.

The free jet can already be used for short experimental objects. The test cage for long models is being made in a length of 3 metres, sketched in Figure 1. The framework for holding the longitudinal strips forming the cage is of such steady construction that the model and the measuring probes can be attached to it. Compared with the completely open free jet, the cage naturally complicates the construction and increases the difficulty of making the experiments. For inserting the model, therefore, the front part of the cage can be opened up on hinges. Since the entire construction is in any case novel, it is intended to acquire some practical experience before the test section is extended to 5 or 6 metres.

The air return occurs freely in the laboratory, which causes annoyance through draughts in the present relatively narrow laboratory. In the plans of the new building for the Institute provision has already been made to add to the tunnel a closed air return following the test length. This will also increase the efficiency of the tunnel and the maximum attainable speed.

A further novel feature is the method whereby the air velocity is regulated and above all kept constant. An electronic control has been provided for this purpose, which will keep the speed of the blower motor constant to within a few tenths of a percent, independently of the jet loading and fluctuations in the mains.

E.L.

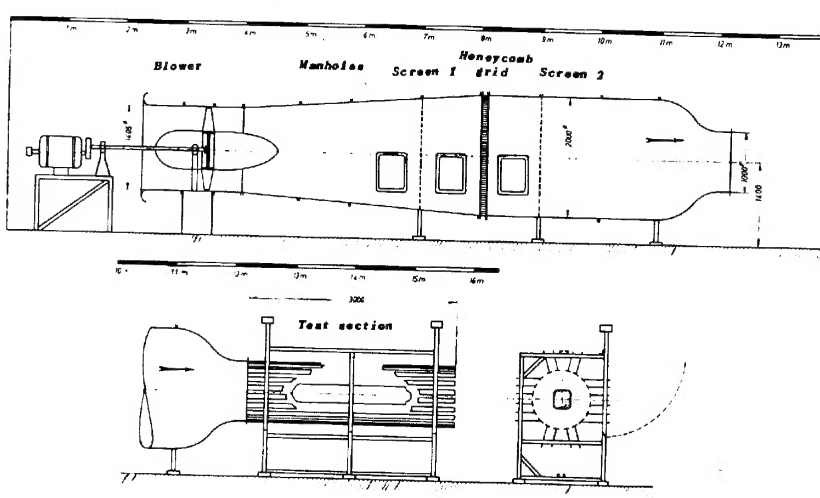

Fig.1: The wind tunnel of the Shipbuilding Institute